NEWTON'S APPLE®

Multimedia

Glaciers

Geothermal Energy

Teacher's Guide

NEWTON'S APPLE Multimedia

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Glaciers

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Introduction

Welcome to the *Newton's Apple* Multimedia Collection™!

Drawing from material shown on public television's Emmy-award-winning science series, the multimedia collection covers a wide variety of topics in earth and space science, physical science, life science, and health. Each module of the *Newton's Apple Multimedia Collection* contains a CD-ROM, a printed Teacher's Guide, a video with two *Newton's Apple* ® segments and a scientist profile, and a tutorial video.

The Teacher's Guide provides three inquiry-based activities for each of the topics, background information, assessment, and a bibliography of additional resources.

The CD-ROM holds a wealth of information that you and your students can use to enhance science learning. Here's what you'll find on the CD-ROM:

- two full video segments from *Newton's Apple*
- additional visual resources for each of the *Newton's Apple* topics
- background information on each topic
- a video profile of a living scientist working in a field related to the *Newton's Apple* segments
- an Adobe Acrobat® file containing the teacher's manual along with student reproducibles
- UGather® and UPresent® software that allows you and your students to create multimedia presentations
- QuickTime® 3.0, QuickTime® 3 Pro, and Adobe Acrobat® Reader 3.0 installers in case you need to update your current software

The *Newton's Apple Multimedia Collection* is designed to be used by a teacher guiding a class of students. Because the videos on the CD-ROM are intended to be integrated with your instruction, you may find it helpful to connect your computer to a projection system or a monitor that is large enough to be viewed by the entire class. We have included a videotape of the segments so that you can use a VCR if it is more convenient. Although the CD-ROM was designed for teachers, it can also be used by individuals or cooperative groups.

With the help of many classroom science teachers, the staff at *Newton's Apple* has developed a set of lessons, activities, and assessments for each video segment. The content and pedagogy conform with the National Science Education Standards and most state and local curriculum frameworks. This Teacher's Guide presents lessons using an inquiry-based approach.

If you are an experienced teacher, you will find material that will help you expand your instructional program. If you are new to inquiry-based instruction, you will find information that will help you develop successful instructional strategies, consistent with the National Science Education Standards. Whether you are new to inquiry-based instruction or have been using inquiry for years, this guide will help your students succeed in science.

WE SUPPORT THE NATIONAL SCIENCE EDUCATION STANDARDS

The *National Science Education Standards* published by the National Research Council in 1996 help us look at science education in a new light. Students are no longer merely passive receivers of information recorded on a textbook page or handed down by a teacher. The Standards call for students to become active participants in their own learning process, with teachers working as facilitators and coaches.

Newton's Apple's goal is to provide you with sound activities that will supplement your curriculum and help you integrate technology into your classroom. The activities have been field tested by a cross section of teachers from around the country. Some of the activities are more basic; other activities are more challenging. We don't expect that every teacher will use every activity. You choose the ones you need for your educational objectives.

Teacher's Guide

We suggest you take a few minutes to look through this Teacher's Guide to familiarize yourself with its features.

Each lesson follows the same format. The first page provides an overview of the activity, learning objectives, a list of materials, and a glossary of important terms. The next two pages present a lesson plan in three parts: ENGAGE, EXPLORE, and EVALUATE.

- ENGAGE presents discussion questions to get the students involved in the topic. Video clips from the *Newton's Apple* segment are integrated into this section of the lesson.
- EXPLORE gives you the information you need to facilitate the student activity.
- EVALUATE provides questions for the students to think about following the activity. Many of the activities in the collection are open-ended and provide excellent opportunities for performance assessment.

GUIDE ON THE SIDE and TRY THIS are features that provide classroom management tips for the activity and extension activities.

USING THE CD-ROM

When you run the *Newton's Apple* CD-ROM, you will find a main menu screen that allows you to choose either of the two *Newton's Apple* topics or the scientist profile. Simply click on one of the pictures to bring up the menu for that topic.

Main Menu

Once you have chosen your topic, use the navigation buttons down the left side of the screen to choose the information you want to display.

Topic Menu

The Background button brings up a short essay that reviews the basic science concepts of the topic. This is the same essay that is in the Teacher's Guide.

Playing the Video

The Video button allows you to choose several different clips from the video segment. We have selected short video clips to complement active classroom discussions and promote independent thinking and inquiry. Each video begins with a short introduction to the subject that asks several questions. These introductory clips can spark discussion at the beginning of the lesson. The Teacher's Guide for each activity presents specific strategies that will help you engage your students before showing the video. Each of the individual clips are used with the lesson plans for the activities. The lesson plan identifies which clip to play with each activity.

Video Menu

Once you select a video and it loads, you'll see the first frame of the video segment. The video must be started with the arrow at the left end of the scroll bar. As you play the video, you can pause, reverse, or advance to any part of the video with the scroll bar. You can return to the Clips Menu by clicking on the Video button.

Multimedia Tools

The *Newton's Apple* staff has designed a product that is flexible, so that you can use it in many different ways. All of the video clips used in the program are available for you to use outside the program. You may combine them with other resources to create your own multimedia presentations. You will find all the video clips in folders on the CD-ROM. You may use these clips for classroom use only. They may not be repackaged and sold in any form.

You will also find a folder for UGather™ and UPresent™. These two pieces of software were developed by the University of Minnesota. They allow you to create and store multimedia presentations. All of the information for installing and using the software can be found in the folder. There is an Adobe Acrobat® file that allows you to read or print the entire user's manual for the software. We hope you will use these valuable tools to enhance your teaching. Students may also wish to use the software to create presentations or other projects for the class.

Technical Information

Refer to the notes on the CD-ROM case for information concerning system requirements. Directions for installing and running the program are also provided there.

Make sure you have the most current versions of QuickTime® and Adobe Acrobat® Reader installed on your hard drive. The installation programs for QuickTime 3, QuickTime Pro, and Acrobat Reader 3.0 can be found on the CD-ROM. Double-click on the icons and follow the instructions for installation. We recommend installing these applications before running the *Newton's Apple Multimedia* program.

Trouble Shooting

There are several Read-Me files on the CD-ROM. The information found there covers most of the problems that you might encounter while using the program.

Integrating Multimedia

We suggest that you have the CD-ROM loaded and the program running before class. Select the video and allow it to load. The video usually loads within a couple of seconds, but we recommend pre-loading it to save time.

All of the video segments are captioned in English. The captions appear in a box at the bottom of the video window. You can also choose to play the clips in either English or Spanish by clicking one of the buttons at the bottom right of the screen. (You can choose Spanish or English soundtracks for the scientist profile.)

The Resources button provides you with four additional resources. There are additional video clips, charts, graphs, slide shows, and graphics to help you teach the science content of the unit.

Resources Menu

The other navigation buttons on the left side of the window allow you to go back to the Main Menu or to exit the program.

NEWTON'S APPLE Multimedia

Geothermal Energy Teacher's Guide

Boiling Over

Why is the Earth hot inside? What makes some places inside the Earth hotter than others? How do volcanoes form and where are they located? Do rocks conduct heat energy? What is geothermal energy, and how can it be used?

Themes and Concepts

- volcanoes
- energy resources
- heat transfer
- processes that shape the Earth

National Science Education Content Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of motions and forces and transfer of energy.
Content Standard D: Students should develop an understanding of the structure of the earth system.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. *Letting Off Steam—Approx. 20 min. prep; 45 min. class time*
How do volcanoes form and what happens when they erupt? What is magma and why does it rise up out of volcanoes? Using simple materials, students build their own "volcano in a bottle" and find out that a little heat has a lot of potential.

2. *Hot Rocks—Approx. 20 min. prep; 45 min. class time*
Students discover why some places inside the Earth are hotter than others and how engineers evaluate the geothermal potential of an area. Students determine how well rocks conduct heat energy by conducting a controlled hot rock experiment.

3. *Turning Turbines—Approx. 20 min. prep; 45 min. class time*
How do geothermal power plants work and what are some of the problems associated with their operation? Students explore how electricity can be generated using geothermal energy and, building a model turbine, they discover how design affects efficiency.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

International Geothermal Association
http://www.demon.co.uk/geosci/igahome.html
(A great overview of geothermal energy with links to other sites.)

Geothermal Education Office
http://marin.org/npo/geo/pwrheat.html
(A super overview with lots of questions and answers.)

Geothermal Technologies—U.S. Dept. of Energy
http://www.eren.doe.gov/geothermal/history.html
(A great summary of the history of geothermal development in the United States.)

Geothermal Energy Technical Site—U.S. Dept. of Energy
http://doegeothermal.inel.gov
(A good site that includes maps showing geothermal potential and current geothermal sites.)

Geothermal Energy

Internet Search Words
geothermal, hot springs, volcanoes, alternative energy

Video Resources
3-2-1 Classroom Contact—Volcanoes
Available from G.P.N.

Books and Articles
Edwards, L. M. *Handbook of Geothermal Energy*. Houston: Gulf Publishing, 1982. (A good technical guide on the development of geothermal energy.)

Jacobs, Linda. *Letting Off Steam: The Story of Geothermal Energy.* Minneapolis: Carolrhoda Books, 1989. (An excellent overview.)

Lambert, David. *Earthquakes and Volcanoes.* New York: Bookwright Press, 1986. (A good general overview of earth processes.)

Lemonick, Michael. "Hot Tempers In Hawaii." *Time Magazine*, August 13, 1989. p68. (A review of geothermal development in Hawaii.)

Robinson, A. *Earth Shock.* London: Thames & Hudson, 1993. (An excellent overview of dynamic earth processes.)

Other Resources
Earth Chronicles, published six times each year in *Earth Magazine.* Waukesha, WI,: Kalmbach Publishing Co. (414) 796-8776
(This is a listing of all major earthquake, volcano, hurricane, and tornado activity for the previous two-month period.)

Community Resources
A local power plant
Heating engineer
Geology department at a local college or university

Background

What would you think if someone said they could build a power plant that could generate a continuous supply of electricity without burning any fuel, without damming a river, and without creating any pollution? Too good to be true? Not if you live near a volcano.

Unless you've seen a volcano erupt or at least spent some time relaxing in a natural hot spring, it's hard to realize just how much heat there is in the Earth. And that heat can be converted to electricity. Geothermal power plants that tap into hot spots just below Earth's surface are springing up all around the globe. And they are becoming one of the most popular forms of alternative energy.

Known as geothermal energy, most of the subsurface heat is produced when elements like uranium, thorium, rubidium, and potassium undergo small-scale nuclear fission as a result of radioactive decay in the upper mantle and crust of the Earth. This nuclear process forms pools of molten rock, called magma, far below the surface. In addition, plumes of magma believed to rise from Earth's core contribute to these pools. The magma rises through the denser, colder rock that surrounds it and, if it has enough energy, sometimes breaks through the surface to form a volcano.

Quite often, the magma doesn't make it all the way to the surface. Just below the surface this super hot mass heats water flowing through the ground above, turning it to steam. It is this natural steam that engineers hope to use to drive power plants in the future.

Power from the Earth isn't anything new. The idea of using natural heat from the Earth dates back at least to the ancient Romans, who used hot springs to heat baths. Today, many buildings in Iceland, Japan, and other countries use geothermal energy for heating. Unfortunately, you have to live near a hot spring to do this. In the early 1900s, engineers in Larderello, Italy, tried to broaden the use of geothermal energy by building an electrical generating plant powered by geothermal steam. They trapped the steam coming from the ground and used it to spin a turbine, which drove an electric generator. Once the electricity was generated, it could be sent via transmission lines to a much larger area.

Natural steam vents that have enough volume and pressure to drive a turbine are actually quite rare, so engineers have developed ways to give nature a boost. By drilling wells up to four kilometers deep into naturally hot rocks and then injecting cool water from the surface, they can heat the water under pressure to about 200° Celsius. When the super-heated water is returned to the surface and depressurized, it flashes into steam and is used to drive electric generators.

Let's face it, geothermal energy is one hot topic!

Video & Stills

Video Segments

Introduction

17:56 to 18:42—Dave Huddleston wonders about the use of lava from volcanoes as a heat source. (46 sec.)

Video Clip 1

18:46 to 20:54—Peggy Knapp tells why Hawaii is such a good place to observe geothermal energy at work. (2 min. 8 sec.)

Video Clip 2

20:59 to 22:25—Volcanologist Christina Heliker explains how volcanoes form and help produce geothermal energy. (1 min. 26 sec.)

Video Clip 3

22:26 to 24:47—Peggy Knapp finds out what makes a good site for exploiting geothermal energy. (2 min. 21 sec.)

Video Clip 4

24:47 to 26:07—A geothermal power plant harnesses rising steam from heated underground water. (1 min. 20 sec.)

Additional Resources

Button A

Video: Aerial footage of the Mount St. Helen eruption

Button B

Diagram: World map of the "ring of fire"

Button C

Diagram: Map showing geothermal potential within the United States

Button D

Slide Show: Diagram of different geothermal power plants

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the video segment and the Background section in this guide. The assessment does not require completing all of the activities. The Unit Assessment may be used as a pre- or post-test. However, students should view the complete *Newton's Apple* video before doing this assessment. There is additional assessment at the end of each activity.

Think about it.

1. Geothermal resources are found near volcanoes because an underground heat source is required for geothermal energy. Active volcanoes are always located above hot magma.

2. Geothermal energy is free, and it is renewable. Also, geothermal energy does not pollute the environ ment. Disadvantages are the limited accessibility to geothermal energy.

3. In addition to producing electricity, geothermal energy may be used to heat swimming pools, baths, and some buildings.

4. Areas of the world near active volcanoes are the best for building a geothermal plant, because the heat of magma is necessary to produce steam from water.

5. Engineers inject cool water into hot rocks beneath the surface to produce high-pressure steam to power a generator.

What would you say?

6. d 7. a 8. c 9. b 10. a

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Unit Assessment

What do you know about Geothermal Energy?

Write the answers to these questions in your journal or on a separate sheet of paper.

Think about it.

1. Why are geothermal resources often located near volcanoes?

2. What are some of the advantages that geothermal energy has over other sources of power generation? What are some disadvantages?

3. In addition to producing electricity, what are some other ways that geothermal energy may be used?

4. Which regions of the world would seem to be ideally suited for geothermal energy?

5. What do engineers do to use relatively weak natural steam vents so that they can produce electricity?

What would you say?

6. How was geothermal energy used in the past?
   a. To heat baths and spas.
   b. To provide hot water for people to cook with.
   c. To heat buildings.
   d. All of the above.

7. Hot magma rises toward the surface of the Earth because—
   a. it is less dense than the surrounding rock.
   b. it is being pushed up from the core by water deep down.
   c. it is being squeezed by rocks coming together in earthquakes.
   d. the core of the Earth is exploding out.

8. Most of the heat found inside the Earth comes from—
   a. nuclear bomb blasts.
   b. the burning of ancient fossil fuel deposits.
   c. the decay of radioactive elements in the rock.
   d. None of the above.

9. Where could you expect to find a good site for geothermal energy?
   a. In a hot desert.
   b. Near an active volcano.
   c. Anywhere on the floor of the ocean.
   d. Under large cities.

10. To use hot water in the Earth for geothermal energy, the water must—
    a. be in the form of steam under high pressure.
    b. be very clean so it does not pollute the surface of the Earth.
    c. be hot enough to use for cooking.
    d. be cooled before it reaches the geothermal plant.

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Activity 1

Letting Off Steam

What is geothermal energy and where does it come from? How does geothermal energy get to the earth's surface? How is geothermal energy related to volcanoes? Why do volcanoes erupt? What makes magma flow from one place to another? What happens to the density of liquids when they are heated?

Getting Ready

Overview

What does geothermal energy have to do with volcanoes? Students learn about geothermal energy and volcanoes. Using soda bottles filled with water, they explore what happens to the density of a liquid when it is heated, and they discover why lava erupts from a volcano.

Objectives

After completing this activity, students will be able to—

- predict what happens to the density of liquids when they are heated and cooled
- explain how a volcano forms and how temperature affects the viscosity of lava
- demonstrate how to conduct a controlled experiment

Time Needed

Preparation: approximately 20 minutes
Classroom: approximately 45 minutes

Materials

For the teacher:

- jar of molasses and a plastic bowl
- cooler of ice
- source of hot water

Each team of students:

- cold water
- lump of water proof clay the size of a small egg
- 1 liter clean plastic soda bottle
- clear plastic straw
- portable hair dryer
- red food coloring
- large disposable aluminum pan
- sponges or paper towels for cleaning spills
- watch or clock with a second hand

Important Terms

density — A measure of how much mass an object has in relationship to its volume

geothermal energy — Heat produced inside the Earth by the radioactive decay of elements.

hot spot — A stationary point in the upper mantle of the Earth that has a high concentration of geothermal heat.

lava — Hot molten rock flowing out of a volcano.

magma — Hot molten rock below the ground surface.

mantle — The layer of the Earth below the crust.

viscosity — The resistance to flow by a liquid. The greater the viscosity, the slower the flow.

Geothermal Energy

Here's How

Video Clip 1
18:46 to 20:54—Peggy Knapp tells why Hawaii is such a good place to observe geothermal energy at work. (2 min. 8 sec.)

Video Clip 2
20:59 to 22:25—Volcanologist Christina Heliker explains how volcanoes form and help produce geothermal energy. (1 min. 26 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 1 for each student.
- Place the jar of molasses in a cooler full of ice at least 30 minutes before class.
- Review the information in the Background on page 8.

Engage (Approx. 15 min.)

Ask students to name some of the devices they have at home that run on electricity. Ask them where the electricity comes from that runs the device. (a socket, electric wires to the home, power plant) Ask the students what sources of energy can be used to produce electricity. (Coal, oil, nuclear, wind, water, solar, and geothermal energy.) Explain that much electric power comes from coal- or oil-burning power plants. In some parts of the country and world, electricity is also produced from nuclear energy and hydroelectric power. Ask the students to think of some disadvantages of using coal, oil, dams, or nuclear reactors to produced electricity. (Coal and oil pollute the environment, and they are not renewable; dams on rivers disturb the local ecology; and nuclear plants produce radioactive by-products.) Ask students what the advantages of geothermal energy might be. (This source of power does not pollute the air or water, and the energy is inexpensive to produce.)

Ask the students if geothermal energy is used where they live. Why or why not? Ask students where geothermal energy is most likely to be found. Show Video Clip 1 [18:46 to 20:54], and ask the students why volcanic areas are good for producing geothermal energy. (There is a lot of underground heat near volcanoes.) Ask them what makes Hawaii such a good place to observe geothermal energy at work. (The Hawaiian islands were formed by volcanic activity, and the islands have active volcanoes.)

In Video Clip 1, Dr. Christina Heliker gives the temperature of the flowing lava at about 1160° C. Most kitchen ovens only get up to about 275° C, so flowing lava is almost five times hotter! The heat of lava can melt aluminum, lead, and gold. It's also hot enough to boil mercury and magnesium!

Ask what factors might control the flow of a liquid. Accept all answers. Take the molasses out of the cooler and pour some of it into a bowl. Have the students observe how slowly it flows; then place the jar in a bowl of warm water. Ask them to predict what might happen to the viscosity once the molasses has warmed up. (It will flow more freely.) Lead students to the conclusion that temperature is a major factor in the flow of a liquid.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [17:56 - 18:42]. Find out what students already know about geothermal energy. As a class, discuss the questions posed by Dave Huddleston.
- Caution students to follow established safety standards, particularly when handling the hair dryer near water.
- Warn the students not to squeeze the bottle when they are warming it with their hands, because pressure will make the water come shooting out.
- In order to have the results reflect only changes in water density, have students make sure that there is no air in the bottle.
- If it is appropriate, view the entire *Newton's Apple* video segment on geothermal energy after completing the activity.

Activity 1

Show Video Clip 2 [20:59 to 22:25]. Ask students what magma is and how it builds a volcano. Ask students what a rift zone on a volcano is. (Weak areas on the side of a volcano where hot magma or lava might break out.) Ask students what scientists can learn from a sample of the lava in a volcano. (The minerals in the sample can tell how likely another eruption is, how deeply the magma is stored underground, and the amount of water in the ground.)

Take the molasses out of the warm water. Have students observe how the warmed molasses flows. Were their predictions correct? Ask them how the molasses is similar to the magma in a volcano. (When heated, it is less dense and it flows more easily.)

Explore (Approx. 30 min.)

Have students fill their soda bottles almost to the top with cold water, and then add three or four drops of red food coloring so that the water turns bright red. Tell students to place the clear plastic straw into the mouth of the bottle so that about 2 cm of the straw are in the water. At least 10 cm of the straw should stick out of the top of the bottle. Tell students to pack the clay around the mouth of the bottle so that the straw is held tightly on the top. The clay should form an airtight seal between the straw and the bottle.

Have students place the mini-volcano into a large pan or basin to catch any overflow, and then have each member of the team place one hand on the bottle to begin to warm it up. Observe what happens to the level of the water in the straw as the water starts to get warm. Explain that this is something like the "hot spot" which is heating the magma below the Hawaiian islands.

Have the students turn on the hair dryer and point it at the bottom of the bottle. Tell them to begin timing as soon as they turn on the hair dryer, and to keep track of how many seconds it takes for the water to rise up to the very top of the straw. When the water rises to the top of the straw, have them stop heating the bottle and record how many seconds it takes for the liquid to move back down into the bottle. In each team, only one person should use the hair dryer, and that student should not handle water.

After the first trial, have students repeat the experiment two more times, and record the time it takes for the water to rise and fall. Ask students to make conclusions about the flow of magma below a volcano based on the results.

Evaluate

1. Based on your experiments, explain how water rising up the tube of your mini-volcano relates to hot magma rising up toward the surface of the Earth. (As a liquid gets hot, it expands. Because the volume increases, the density decreases so both the water and magma rise.)

2. How does lava flowing from the vent of a volcano change as it cools? Is density the only factor that slows the flow? (As it cools, it gets thicker—more viscous, and the greater viscosity slows the flow.)

Try This

All volcanoes aren't created equal. Some, like the ones in Hawaii, erupt frequently, release large amounts of lava, and cause very little damage. Others, like Mount St. Helens in the state of Washington, erupt only on occasion, but when they do, they devastate an area. What factors control when and how a volcano erupts, and how might scientists use this information for developing geothermal resources?

Magma in a volcano isn't the only liquid that rises due to changes in density. Thermometers use changes in density of mercury or alcohol to measure changes in temperature. Try building your own thermometer in a bottle.

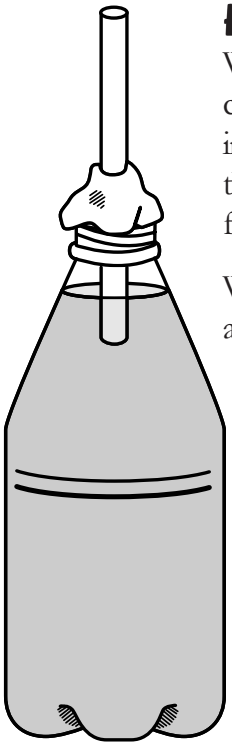
LETTING OFF STEAM

Activity Sheet 1

NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You're going to simulate the action of an erupting volcano using a soda bottle, water, a straw, and a piece of modeling clay.



HOW TO DO IT

Work with your group. Fill a soda bottle completely with cold water and place a clear plastic straw into the mouth of the bottle so that about 2 cm of the straw are in the water and at least 10 cm extend out of the top of the bottle. Pack clay around the mouth of the bottle so that the straw is held firmly in place. The clay should form an airtight seal between the straw and the bottle.

With the members of your group, put your hands around the bottle to warm it for about a minute. Record your observations. Point the hair dryer at the bottom of the bottle and time how long it takes for the liquid to rise to the top of the straw. Shut off the hair dryer and time how long it takes for the water to fall back into the bottle. Record the results in your journal. Repeat the experiment two more times.

RECORDING YOUR DATA

Create a data table in your science journal to record the following kinds of information for each trial.

Trial #_____

Time for water level to reach the top of straw: _____ sec.

Time for water level to go back down into the bottle: _____ sec.

Other observations:

WHAT DID YOU FIND OUT?

What happened to the amount of time that it took for the water to rise up the straw each time you heated the bottle? How might you explain this?

In this experiment, what did the hair dryer represent from a real volcano?

What do you think would have happened to the speed of your eruption if you had used a bottle which held twice as much water? Why?

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Activity 2

Hot Rocks

What happens to the temperature of rocks deep in the Earth? Can rocks conduct energy? What makes an area ideal for producing geothermal energy? Why do areas near magma have the greatest geothermal potential?

Getting Ready

Overview

The activity begins with a demonstration of how geothermal energy can be used to heat water. Then students investigate how earth conducts heat energy. Students create a model to determine how changing the distance to a magmatic body controls the geothermal potential of an area. Based on their experiments, students determine how the geothermal gradient is an indicator of the potential for geothermal energy in an area.

Objectives

After completing this activity students will be able to—

- explain what is meant by the geothermal gradient
- describe some of the factors that scientists look for when assessing the geothermal potential of an area

Time Preparation

Preparation: approx. 20 min.
Classroom: approx. 45 min.

Materials

For the teacher:

- hot plate
- 400 ml Pyrex beaker
- 400 ml of coarse gravel
- aluminum cake pan approximately 8" square
- lab thermometer
- oven thermometer
- large (75 ml or larger) test tube
- 100 ml of cool water
- oven mitt

Each team of students:

- 3 plastic glasses (12 oz size) or large test tubes/beakers
- 1000 ml of fine, dry sand
- 3 lab thermometers
- metric ruler
- large (20 cm x 30 cm plastic or metal pan filled with 3 cm of hot water
- stop watch
- masking tape and markers

Important Terms

flash — A process where super-heated water is turned into steam.

geothermal gradient — The increase in temperature of the surrounding rock as you move down from the Earth's surface.

geothermal reservoir — A natural collection of hot water under the ground from which energy can be tapped.

injection well — A deep well in which cold water is "injected" into the ground to be heated by the surrounding rock.

steam vent — A hole in the ground from which natural hot steam appears.

Geothermal Energy

Here's How

Video Clip 3
22:26 to 24:47—Peggy Knapp finds out what makes a good site for exploiting geothermal energy. (2 min. 21 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 2 for each student.
- Review the information in the Background on page 8.
- Before class, pour the gravel into the aluminum pan and place it on the hot plate to heat it. Use an oven thermometer to monitor the temperature of the gravel in the pan. Fill the large test tube with cool tap water and place a thermometer in it to record its temperature.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [17:56 - 18:42]. Find out what students already know about geothermal energy. As a class, discuss the questions posed by Dave Huddleston.

- How does moisture affect the ability of rock to conduct heat? Will varying amounts of moisture produce varying effectiveness of conduction? If time permits, have the students repeat the experiment using wet sand instead of dry sand.

- In this experiment sand is used because it's easier to measure the temperature at different levels. Is this really a true test of geothermal energy? In most geothermal areas the heat is conducted through solid rock. Ask the students to consider how air space between the grains of sand might affect the results. How might they revise the experiment to find out how solid bedrock conducts heat?

- If it is appropriate, view the entire *Newton's Apple* video segment on geothermal energy after completing the activity.

Engage (Approx. 15 min.)

At the beginning of class, have a student read the temperature of the water in the test tube and the temperature of the gravel in the aluminum pan on the hot plate. Record the temperatures on the board. Place the test tube with the thermometer into the middle of the 400 ml beaker and hold it vertically. Carefully pour the hot gravel into the beaker so that it completely surrounds the test tube. Ask the students to predict what will happen to the temperature of the water and how much of a change will occur.

Show Video Clip 3 [22:26 to 24:47], and ask students what the best area is for geothermal prospecting—an area near the lava pond or one on the volcanic rift? (An area on the volcanic rift.) What are some things prospectors might look for? (Steam rising, warm soil, dead vegetation.) What is an essential element for the practical use of geothermal energy? (There must be a source of high-pressure steam.)

Following the discussion, check the temperature of the water in the test tube. Review the results and compare them to the students' predictions. Ask students what the demonstration shows about the potential for geothermal energy.

Explore (Approx. 30 min.)

Ask students if to discuss their ideas about how authorities determine whether a particular area might have accessible geothermal energy. What sort of device might they use? Explain to the students that they are going to measure a geothermal gradient.

Have the students work in teams. They should fill three plastic cups with equal amounts of clean, dry sand, making sure that there is at least 10 cm of sand in each cup. Use masking tape and markers to number the cups "1," 2," and "3."

Activity 2

Tell the students to insert the thermometer into cup 1 all the way to the bottom of the sand. Next, they insert a second thermometer into cup 2 so that the base of the thermometer is exactly 5 cm above the bottom of the cup. Finally, students insert a third thermometer into cup 3 so that the base of the thermometer is exactly 7 cm above the bottom of the cup. Have students record the reading of each thermometer in their journals.

Have the students place all three cups into the pan full of hot water and begin timing. Have students check the temperatures in the three cups every 10 to 20 seconds, and after one minute has passed, have them record the reading of each of the three thermometers. Students continue timing for a total of five minutes, recording the temperature for each sample every minute.

After five minutes have elapsed, have students stop recording and plot their data for each cup on a graph showing time and temperature.

Evaluate

1. The average geothermal gradient in the Earth is about 25°C per kilometer of depth. That means that it gets 25 degrees hotter for each kilometer of depth into the Earth. About how far would you have to drill into the Earth to find rocks hot enough to make steam? How does this limit geothermal development? (Water turns to steam at 100° C. If you consider the average surface temperature to be 25°C, you would have to drill at least three kilometers to reach the desired temperature. This is usually too costly to do.)

2. Based on the video and class discussions, list four clues that scientists look for to decide whether an area might be suitable for geothermal development. (Steam vents, dead vegetation, volcanic activity, hot soil temperature.)

3. During the energy crisis of the 1970s, one idea that was suggested to save on heating costs was to have houses underground, because they would be insulated by soil and rock. Based on your experiments, does Earth make a good insulator?

Try This

Even though geothermal energy sounds like a great solution for long-term energy production, it is not the perfect energy source because it can only be developed in areas where there is magmatic activity. Using a map of the world, locate areas where geothermal energy is now being used and suggest what areas might be prime candidates for geothermal development in the future.

In areas where the geothermal reservoir is really deep, engineers use a device called a ground water heat pump to preheat water for domestic heating or cooling. Do some research on how these devices work and try to design a working model of your own.

HOT ROCKS

Activity Sheet 2

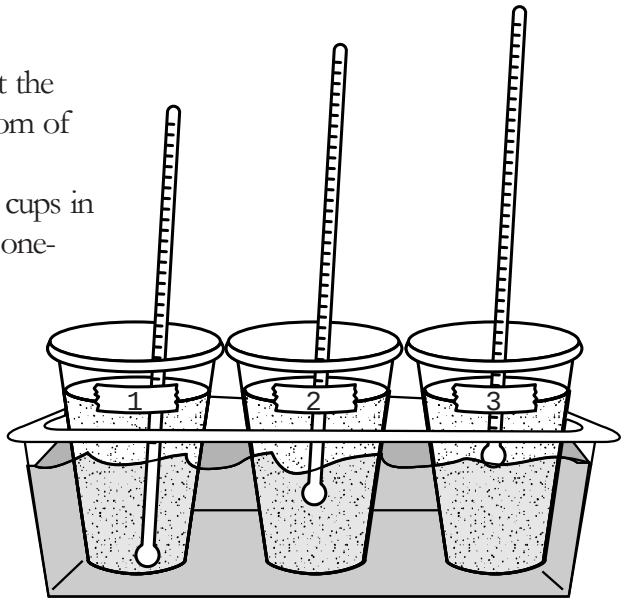
NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You're going to find out how a local geothermal gradient can indicate the potential for geothermal energy in an area.

HOW TO DO IT

Fill up three cups with clean dry sand and place a thermometer at the bottom of cup 1. Place another thermometer 5 cm from the bottom of cup 2. Place a third thermometer 7 cm from the bottom of cup 3. Record the initial temperature of the water in each cup. Place the cups in the hot water bath and record the temperature changes in each at one-minute intervals.



RECORDING YOUR DATA

Temperature	Cup 1	Cup 2	Cup 3
Initial temp.	_____	_____	_____
1 minute	_____	_____	_____
2 minutes	_____	_____	_____
3 minutes	_____	_____	_____
4 minutes	_____	_____	_____
5 minutes	_____	_____	_____

Make a graph and plot the temperature and time for each of the three cups. Calculate the thermal gradient at the beginning and end of the trials. Use this formula: change in temperature ÷ change in depth.

WHAT DID YOU FIND OUT?

In this experiment, what did the hot water represent? What did the sand represent?

Which of the three thermometers showed the greatest amount of temperature change? Which showed the least? How can you explain these results?

Based on your experimental data, why is it important that bodies of magma be located near the surface in areas using geothermal energy?

How might this experiment be changed so that the heat from the water better represented heat from the Earth?

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Activity 3

Turning Turbines

How can geothermal energy produce electricity? What are the major components found in a geothermal energy plant? What is a turbine? How does a turbine work? What are some ways the efficiency of a geothermal plant can be improved?

Getting Ready

Overview

Students explore how geothermal energy is converted into electricity. The activity begins with a quick demonstration of how steam can be converted to mechanical energy, and how increasing the pressure of the steam allows more work to be accomplished. Students construct model turbines and experiment with designs to maximize the efficiency of operation. Students also learn about some of the limitations associated with a geothermal power plant.

Objectives

After completing this activity students will be able to—

- describe the components found in a geothermal system
- explain how a turbine can be designed to provide maximum efficiency
- demonstrate how mechanical energy can be converted into electrical energy

Time Needed

Preparation: approx. 20 min.
Classroom: approx. 45 min.

Materials

For the teacher:

- oven mitt
- hot plate
- 250 or 400 ml Pyrex boiling flask
- water
- one-hole rubber stopper to fit the flask
- 15 cm glass tube to fit inside the stopper
- plastic pin wheel (If you don't have a pin wheel, you can make one by punching a hole through the center of a 6 inch paper plate. Cut and fold four flaps to make the blades.)

Each team of students:

- student activity sheet
- pencil
- 30 cm ruler
- spool of thread
- (2) thin (0.50 mm) plastic drinking straws
- roll of cellophane tape
- pair of scissors
- 3" x 5" index card

Important Terms

generator — A device that produces electrical current using a magnet spinning within a large coil of wire.

heat exchanger — A device that takes heat from one source and transfers it to another substance.

psi — The abbreviation for pounds per square inch. The relative pressure of a gas.

turbine — A device that resembles a giant fan used to capture the energy of a moving fluid and turn it into a spinning motion.

Geothermal Energy

Here's How

Video Clip 4
24:47 to 26:07—A geothermal power plant harnesses rising steam from volcano-heated underground water. (1 min. 20 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the information in the Background on page 8.
- Before class, fill the flask about half full with water and insert the stopper with the glass tube snugly into the top. The bottom of the glass tube should be at least 2 cm above the level of the water in the flask. Place the flask on the hot plate and begin heating so that the water is near the boiling point when the class arrives.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [17:56 - 18:42]. Find out what students already know about geothermal energy. As a class, discuss the questions posed by Dave Huddleston.

- While students are experimenting with their turbines, advise them to try changing the following variables:
1) add extra blades of paper to find out if the number of blades on a turbine makes a difference in the way it spins;
2) change the size of the blades to find out if surface area is an important factor;
3) bend the blades to see if the angle at which the air hits them affects performance. Make sure students record their modifications and the results of their experiments in their journals.

- When they blow on the turbine, students should always hold the turbine the same distance from the end of the straw and angle the straw the same way.

- If it is appropriate, view the entire *Newton's Apple* video segment on geothermal energy after completing the activity.

Engage (Approx. 15 min.)

Begin class by asking students if they know how steam is used to make electricity in a power plant. Discuss the process briefly and using the flask of boiling water and the pin wheel, show how rising steam can make the pin wheel turn. Hold the pin wheel over the top of the glass tube in the flask and turn up the heat. Adjust the pin wheel so that it is in the flow of the steam.

Ask students how geothermal power plants generate electricity. Accept all answers. Then show Video Clip 4 [24:47 to 26:07] Discuss the different components of a power plant and what they do. Ask students how geothermal engineers in Hawaii plan to transmit geothermal energy to nearby islands. Ask students how conventional power plants transmit energy to different locations around the country, and then after the discussion, explain that they are going to experiment to find out how a steam turbine works.

Explore (Approx. 30 min.)

Have students work in small groups. Students wrap cellophane tape around the spool of thread to keep the thread from unraveling off the spool.

Using the pencil, have the students punch out any paper that may be covering the holes at the ends of the spool and then insert the straw through the spool. Ask students to spin the spool on the straw with a finger. The spool should move very smoothly. A bamboo barbecue skewer may be substituted if the straw is too large.

Activity 3

Tell students that they need to build fins on the turbine so that a moving fluid (in this case wind) can spin the spool. Have the students cut a 4 cm x 3 cm rectangle out of the index card, and tape it to the spool so that sticks up out of the side of the spool. Have them hold the spool in front of their mouths and blow through a straw so that the air coming out hits the side of the paper blade. The spool should turn from the force of the air hitting the index card blade.

Ask students to experiment with their turbines and come up with the a design that makes the best use of the air flow to spin the turbine. Tell students to draw a diagram of each turbine design and record its overall performance.

Evaluate

1. Based on their experiments, ask students to explain how changing the number of blades on a turbine effects its overall efficiency. (The more blades, the greater the amount of energy transfer from the fluid to the generator.)

2. Why must the steam in a power plant be under high pressure to be useful? How is steam similar to water and wind? (It must be strong enough to turn a turbine.)

3. What are some of the limiting factors that might prevent geothermal energy from becoming a major power source in the future? (It can only be produced in certain areas and must be distributed over a large area.)

Try This

Have a competition with your friends to see which team can get the fastest spinning turbine. Instead of using a straw to blow on it, use a small fan or a hair dryer as your wind source. This will eliminate some of the critical variables.

Generating electricity using geothermal energy is only one of many ways this resource can be used. How might you put geothermal energy to work? Do research on some of the other uses for geothermal energy and describe any of the pitfalls and problems that geothermal engineers encounter.

Do some research on other means of producing electricity, such as wind, solar, hydroelectric energy, fossil fuel, and nuclear energy. What are some of the similarities and differences between these systems and how do they compare to geothermal energy in terms of cost and environmental impact?

Build a model of a geothermal plant. Once you have built your turbine, try using the steam from a tea kettle to get it to turn. Can you increase the pressure of the steam to get a greater amount of spin?

TURNING TURBINES

Activity Sheet 3

NAME _____ CLASS PERIOD _____

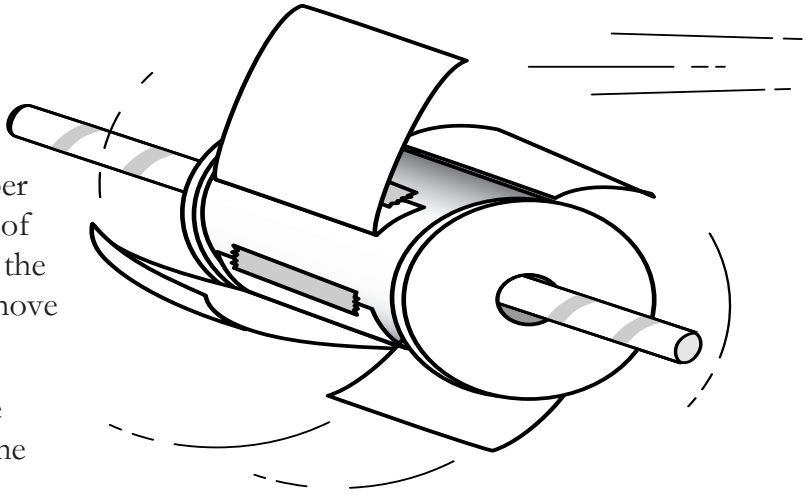
WHAT YOU'RE GOING TO DO

You're going to make a model turbine and experiment with designs to produce maximum turbine efficiency.

HOW TO DO IT

1. Work with your group. Wrap several pieces of cellophane tape around the spool of thread to keep the thread from unraveling off the spool. Next, punch out any paper that may be covering the holes at the ends of the spool, and then insert a straw through the spool. Spin the spool on straw; it should move very smoothly.

2. Cut fins out of an index card, and tape them to the spool so they stick out from the side of the spool and form turbine blades. Hold the spool in front of your mouth and blow on the blades through a straw. The spool should turn from the force of the air hitting the blades, just like a turbine. Experiment with different designs. How can you adjust the blades to make your turbine more efficient? Which design turns more easily when you blow through the straw?



RECORDING YOUR DATA

Draw your designs and record the test results of each of your modifications.

WHAT DID YOU FIND OUT?

In this investigation, why is it important to blow the same way during each trial? How could you eliminate the variable of changing wind speed in the straw you are blowing through?

Which turbine design gave the best results? Which seemed least efficient? Why?

Compare your group's results with designs from other groups. What differences did you find? What similarities?

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Rivers of Ice

What are glaciers? Where can you find them? How old are glaciers? How do they move? What can you learn from glaciers?

Themes and Concepts

- erosion
- processes that shape the Earth
- crystal formation
- glacial movement
- states of matter

National Science Education Content Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of properties of matter and transfer of energy.
Content Standard D: Students should develop an understanding of the structure of the Earth system.
Content Standard G: Students should develop an understanding of the nature of science.

Activities

1. *Slippery When Wet—Approx. 15 min. prep; 1 hr. class time*
How does a glacier move down the side of a mountain? Students discover that it takes more than gravity to move all that weight. The snow melting on the surface of a glacier is involved, and so is the weight of the glacier.

2. *Silly Ice—Approx. 20 min. prep; 45 min. class time*
The plastic characteristic of ice is the topic of discovery. Students simulate the internal deformation of ice and observe and measure the movement of their model glacier.

3. *Shaping the Earth—Approx. 15 min. prep; 1 hr. class time*
Ice is soft enough to be scratched by a fingernail, yet it can actually grind up solid rock. How? Students test their strength against that of a glacier and discover that no amount of force can make ice scratch rock without some abrasive material.

More Information

Internet

Newton's Apple
http://www.ktca.org/newtons
(The official *Newton's Apple* web site with information about the show and a searchable database of science ideas and activities.)

University of Idaho — Juneau Icefield Research Program
http://www.mines.uidaho.edu/glacier/brochure1.html
(Information about the Juneau Icefield Research Program and photographs of glaciers.)

Central Michigan University — Glaciers and Glacial Land Forms
http://www.cmich.edu/~3NRWBHG/glaciers.htm
(Good links to sites related to glaciers and Ice Age topics.)

Internet Search Words

glaciers, climatology, erosion, Ice Age

Glaciers

Books and Articles

Ferguson, Sue. A. *Glaciers of North America: A Field Guide*. Golden, CO: Fulcrum Press, 1992.
(Easy-to-read, descriptive guide to glaciers and glacier travel.)

Kendall, D.L. *Glaciers and Granite*. Unity, Maine: North Country Press, 1987.
(Nontechnical description of glaciers and glacier features in Maine.)

Paterson, W.S.B. *The Physics of Glaciers*. New York: Pergamon Press, 1994.
(Excellent reference for glacier mechanics; college text.)

Pielou, E.C. *After the Ice Age: The Return of Life to Glaciated North America.* Chicago: The University of Chicago Press, 1991.
(Excellent reference for understanding glaciers and the organisms that have flourished since glaciation.)

Community Resources

Local college and university geology departments

Arctic Institute of North America
The University of Calgary
2500 University Drive NW
Calgary, AB Canada T2N 1N4
tel: 403-220-7515

Glacier National Park
P.O. Box 128
West Glacier, MT 59936
tel: 406-888-7800

Background

Imagine a mountain of ice slowly gouging its way through New York City or a mile-thick layer of ice pressing down on the state of Minnesota. During the past few million years, as ice ages have come and gone, huge glaciers have occasionally moved south from the Arctic and covered much of the northern tier of the United States, including Minnesota and New York.

Glaciers form when the amount of snow that falls in an area in winter exceeds the amount of that melts in the summer. As the weight of the snow increases, snow crystals in the glacier are changed from their six-sided form into larger, more compact and flat kinds of ice crystals. Along with this process, summer meltwater from the surface of the glacier percolates down through the snow layers. Crystal change, compression and compaction, and the seasonal flow of meltwater combine to result in a massive formation of dense glacier ice.

Glaciers are slowly flowing rivers of ice. There are two kinds of movement that allow a glacier to flow downward—internal deformation and basal sliding. Here's how they work. As snow crystals are compacted into ice crystals, the crystals align together into flat planes that run parallel to the top and bottom of the glacier, almost like cards in a deck. This process is called internal deformation. These crystalline planes allow the glacier to "slip" internally. Gravity pulls on these crystalline planes and the top portion of the glacier slips downhill. Basal sliding refers to movement of the glacier's base. During the summer, snow melts on top of the glacier. The water flows to the base of the glacier through crevasses and small tunnels inside the glacier. This melt water lubricates the bottom of the glacier, reducing friction with the ground. That allows the glacier to slide more easily on its base. And, again, gravity pulls the glacier downward.

Glaciers are extremely heavy and powerful, eroding the land surface over which they flow. Ice is softer than rock, but moving glaciers push and carry rocks and sand at their base, and these help a glacier scour the land it is moving over. Because glaciers are so large, over time they pick up enormous amounts of material—even large boulders and trees—and push it to the front of the glacier. When a glacier stops advancing and begins to retreat, all of this debris is left in large piles called moraines. Many moraines can still be found in lands that have been subjected to repeated invasions by rivers of ice.

So the next time you see a massive boulder that looks like it has been dropped into the middle of a landscape, remember a glacier may have put it there tens of thousands, perhaps even millions, of years ago!

Video & Stills

Video Segments

Introduction

26:18 to 26:53—SuChin Pak ponders the size of glaciers and the enormous power of these flowing rivers of ice. (35 sec.)

Video Clip 1

27:00 to 30:44—Professor Maynard Miller introduces David Heil to the Taku Glacier and glacier movement. (3 min. 44 sec.)

Video Clip 2

30:44 to 31:52—Under the weight of previous years of snowfall, snow melts and forms glacial ice. (1 min. 8 sec.)

Video Clip 3

31:53 to 34:44—Deep crevasses are formed in glaciers by the internal deformation of ice. (2 min. 50 sec.)

Video Clip 4

34:45 to 36:05—At the terminal end of the Taku Glacier, Professor Miller and David Heil observe the immense erosive power of a moving glacier. (2 min. 20 sec.)

Additional Resources

Button A

Science Try-It: Melting ice with pressure

Button B

Diagram: Cross section of an ice sheet

Button C

Slide show: Retreat of the Grinnell Glacier

Button D

Slide show: Various glacier flows

Unit Assessment Answer Key

The Unit Assessment on the following page covers the basic concepts presented in the video segment and the Background on the Unit Theme section in this guide. The assessment does not require completing all of the activities. However, students should view the complete *Newton's Apple* video before doing this assessment. The Unit Assessment may be used as a pre- or post-test. There is additional assessment at the end of each activity.

Think about it.

1. The cracks are caused by a plastic characteristic of ice. The glacial ice stretches until it cracks; however, lower levels are not stretched as much as upper levels, so they do not crack.
2. Each layer of snow is distinct, so we can label the layers according to the year they fell. Also, the layers contain dust from the atmosphere, and the layers can tell us something about the cleanliness of the air at the time the snow fell.
3. Snow, under the weight of successive layers, becomes ice. The six-sided snow crystals are compressed into flat ice crystals that are aligned in sheets.
4. The terminus recedes because of melting.
5. Pressure turns snow crystals into ice crystals and also causes some of the ice to melt.

What would you say?

6. c 7. a 8. d 9. c 10. a

NEWTON'S APPLE Multimedia

Unit Assessment

What do you know about Glaciers?

Write the answers to these questions in your journal or on a separate piece of paper.

Think about it

1. What causes cracks and crevasses in glaciers? Why do they usually not extend all the way to the bottom of the glacier?

2. In the video, Professor Miller says that we can "read the layers of a glacier like a book." What does he mean?

3. What are some ways that snow that has fallen at the top of a glacier changes by the time it reaches a glacier's terminus?

4. The terminus of a glacier sometimes appears to move up the slope of a mountain. What accounts for this?

5. Explain the role of pressure making glaciers move.

What would you say?

6. Which of the following is not a reason why glaciers move?
   a. internal deformation
   b. gravity
   c. influence of tides
   d. water at the base of a glacier

7. Glaciers move more easily—
   a. in summer when there is more snowmelt.
   b. in the winter when more snow falls.
   c. when moving over rocky surfaces.
   d. at night.

8. As the weight of the snow increases with depth—
   a. each single snowflake increases in size.
   b. snow collects together forming snowballs.
   c. snowflakes still retain their six-sided, crystalline shape.
   d. large, flattened ice crystals form.

9. In the video, internal deformation is called plastic flow. Plastic flow describes a material that—
   a. flows and deforms like molasses.
   b. moves quickly and conforms to its container.
   c. moves when deformed slowly but will break if moved rapidly.
   d. moves when deformed but returns to its original shape.

10. Ice is softer than stone yet a glacier can break up rocks because—
    a. the debris the glacier is pushing grinds up the rocks.
    b. frozen rocks break easily.
    c. glacier ice is harder than normal ice.
    d. All of the above

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Activity 1

Slippery When Wet

How do glaciers move? How fast do they move? Are glaciers always moving? Can we see glaciers move? How does pressure help glaciers move?

Getting Ready

Overview

What role does water play in the movement of glaciers? Using ice cubes, students simulate glacial movement and discover the lubricating power of water. They learn about the role of pressure in melting ice, and they find out how various substances influence the movement of glaciers.

Objectives

After completing this activity, students will be able to—

- identify the factors responsible for glacial movement
- describe the effect of pressure on snow and ice
- discuss the role of water as a lubricant

Time Needed

Preparation: approximately 15 minutes
Classroom: approximately 1 hour

Materials

For the teacher:

- wire cheese cutter and a heavy weight to place on it
- two cookie sheets—one chilled in a freezer and one at room temperature
- several ice cubes

Each group of students:

- at least a dozen ice cubes
- ice cooler to store the ice
- bread board or similar piece of wood
- protractor
- sand
- watch or timer
- gram scale
- small, shallow box (about the size of a throat lozenge box)

Important Terms

friction — The force that acts to resist movement between two surfaces that are in contact with each other.

lubricant — A substance which reduces friction.

basal sliding — The movement of a glacier with the aid of meltwater as a lubricant at the base of the glacier.

internal deformation — The movement of ice caused by gravity and the plastic characteristic of ice.

NEWTON'S APPLE Multimedia

Glaciers

Here's How

Video Clip 1
27:00 to 30:44—Professor Maynard Miller introduces David Heil to the Taku Glacier and glacier movement. (3 min. 44 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 1 for each student.
- Review the information in the Background on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [26:18 - 26:53]. Find out what students already know about glaciers. As a class, discuss the questions posed by SuChin Pak.
- Students should make sure they time the movement between the same two points each trial.
- You may want to supply students with boards that have different types of surfaces. This will enable a better variation in the movement of the ice before any sand is added.
- Four to six ice cubes should be placed together in a thin box, with the ice sticking out above the edge. You may wish to add some water and refreeze the cubes together. The box allows students to attach weights to increase the mass of the "glacier." Place the box ice-side-down on the board. See the illustration on Activity Sheet 1.
- Students should determine the mass of the varying amounts of sand when the sand is dry—prior to sprinkling it on the board.
- Students may want to experiment with different patterns of sand. For example, a thicker layer at the top or the bottom.
- Once the ice has started to melt, it will move quickly, and fresh ice will be needed. Tell the students that if the textures of the boards they have chosen are different, they will have different results in the activity.
- Students use the gram scale to measure the amount of sand they are using on the ramp. The weight of an ice cube might also be a variable. Does a heavier ice cube move more quickly?
- If it is appropriate, view the entire video segment on glaciers after completing the activity.

Engage (Approx. 15 minutes)

What makes ice slippery? Is ice slippery? Ask for reasons that lead students to believe one way or the other. Accept all answers.

Tell the students you are going to demonstrate what makes ice slippery. Take two cookie sheets—one that has been chilled in a freezer, and another that is at room temperature. Put an ice cube of similar size and shape on each sheet and then raise one end of each of the sheets to equal angles of about 20 degrees. Observe what happens. Which ice cube moves along the ramp more quickly? Why? (Melt water from the ice cube lubricates the surface of the warm cookie sheet. The ice cube on the chilled cookie sheet does not move until the ice has begun to melt.)

View Video Clip 1 [27:00 to 30:44] in which Dr. Maynard Miller discusses glacial movement. Ask students to identify the two kinds of movement. (Basal sliding and internal deformation.) What is the source of water for basal sliding that is mentioned in the video? (Snow meltwater that seeps down to the base of the glacier.)

Ask students how the weight of the glacier affects movement. (The weight produces pressure at the base of the glacier.) Lead students to see that this pressure helps to melt some of the ice and create meltwater for lubrication. Tell students that it is pressure that allows skaters to glide smoothly over ice. Explain that a thin layer of meltwater under the blades of ice skates is the result of pressure. Ask students for additional examples of pressure melting ice. (Skis on snow is an example.) Tell the students that there is constantly at least a thin layer of water at the base of a glacier.

Rest the wire portion of a cheese cutter across a thin piece of ice or ice cube on a sponge. Put a weight on the handle of the cheese cutter. Ask students to predict what will happen. Have them observe what happens. (The wire should slowly go into the ice.) Ask students if the wire is cutting the ice or melting the ice. (It is melting the ice.) How do we know? (The melted water refreezes, closing the path of the wire through the ice.)

Ask the class for examples of friction. What causes friction and how is it reduced? (Two surfaces in motion come into contact. Lubricants are used to reduce friction.) Ask students what some factors might be that determine the speed of a glacier's movement. (Amount of water, angle or slope, and amount of friction.) Ask students for the main source of energy for the movement of a glacier. (gravity)

Activity 1

Explore (Approx. 45 minutes)

Tell students that they are going to model the sliding movement of a glacier using ice cubes, sand, and a board. Explain that the goal is to determine the important variables that affect the ability of ice to slide down the board.

Have students work in small groups. Tell them to begin by listing the variables that they think will affect the ability of the ice to slide off the board. Which variables do they think are most important? They should use varying amounts of sand for each trial where sand is a variable. Tell them to experiment with a number of ramp angles between 50 degrees and 20 degrees. However, angle increments should be equal for each trial. Suggest that students use books to prop up one end of the board and use a protractor to measure angles. Have students record the amount of time for the ice to slide off the board for each of the variables. Groups should analyze their data and come up with a conclusion.

Have groups present their conclusions to the entire class. Discuss the results and explore what might have caused any differences from group to group.

Evaluate

1. Ask students to consider a car's wheels spinning in snow or on ice. How does sand work to enable the car to move forward? (A car's wheels spin on ice and snow and produce heat, melting a layer of water for the wheels to slide on. Sand increases friction, so the tires no longer slip.)

2. Which are better ice skating conditions—a cold day when there is no water on the rink, or a warm day when the rink is covered with a centimeter of water? Explain your reasoning. (The cold day is better. Although ice skaters slide on a thin film of water, the friction between the excess water and the blades would slow the skater.)

3. You want to make your ice-covered driveway safe for visitors to walk on. How would chopping grooves in the ice achieve this goal? (Because the ice is not flat, pressure does not work as effectively to melt ice as it does when the surface of the ice is flat. Because people can walk on the ice without a thin layer of water forming under their shoes, the driveway is safer to walk on.)

Try This

Investigate features of glaciers not included in this unit, such as jokuhlaups (pronounced yo-kool-hloips), an Icelandic word that refers to sudden flooding of glacial lakes.

View the *Newton's Apple* Science Try-It found at Button A on the CD-ROM.

SLIPPERY WHEN WET

Activity Sheet 1

NAME _____ CLASS PERIOD _____

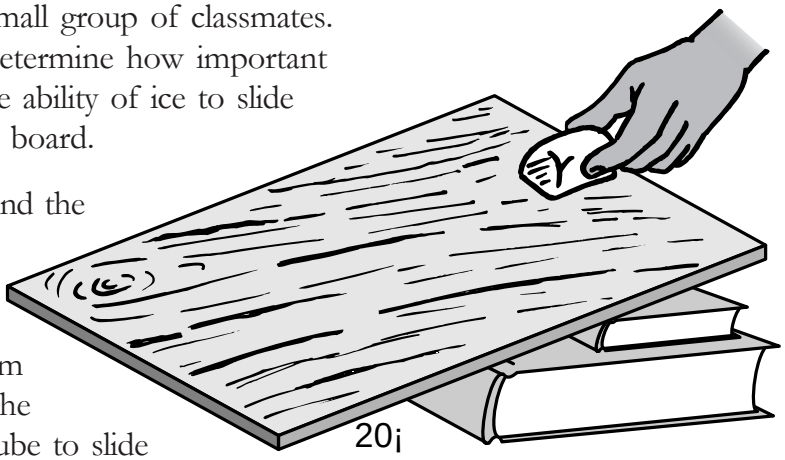
WHAT FACTORS AFFECT ICE MOVEMENT?

WHAT YOU'RE GOING TO DO

You're going to simulate the movement of a glacier using an ice cube, sand, and gravity.

HOW TO DO IT

1. Work with a small group of classmates. Your goal is to determine how important variables affect the ability of ice to slide down an inclined board.



2. Keeping in mind the movement of a glacier, list the variables that you and your team think will affect the ability of an ice cube to slide down the ramp. Which of the variables do you think are the most important?

3. Next, experiment with a number of ramp angles, beginning with a high angle of 50 degrees and gradually lowering the ramp to an angle of 20 degrees. Angle increments should be equal for each trial. Measure the amount of sand you use on the board with a scale. Begin with a small amount and increase it for each trial. Record the amount of time for an ice cube to slide off the board for each of the variables.

RECORDING YOUR DATA

Record the following information for each trial in your journal.

Trial #
Angle of slope
Size of cube
Shape of cube
Amount of sand
Time

Other observations

WHAT DID YOU FIND OUT?

What variable had the greatest effect (positive or negative) on the rate of movement of an ice cube?

Are there variables that affect the movement of an ice cube that would not be as important for the movement of a glacier? Explain your answer.

Compare your results with other groups. Discuss factors that may have caused different results.

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Activity 2

Silly Ice

Are glaciers made of snow or ice? What is internal deformation? How does the plastic characteristic of ice contribute to glacial movement?

Getting Ready

Overview

How does a glacier move down the side of a mountain? In addition to basal sliding, internal deformation contributes to glacial movement. Students simulate this phenomenon and observe and record its characteristics.

Objectives

After completing this activity, students will be able to—

- explain the transformation of snow in a glacier
- describe the movement of a glacier due to internal deformation
- discuss the plastic characteristic of ice

Time Needed

Preparation: approximately 20 minutes
Classroom: approximately 45 minutes

Materials

For the teacher:

- spoonful of honey
- deck of cards
- Silly Putty®

Each team of students:

- 2 disposable cups of the same size
- cornstarch
- 2-liter clear plastic soda bottle
- plastic spoons
- water
- scissors
- shallow dish
- awl

Important Terms

basal sliding — The movement of a glacier with the aid of meltwater as a lubricant at the base of the glacier.

crevasse — A deep crack in glacial ice. Crevasses do not extend to the bottom of a glacier.

internal deformation — The movement of ice caused by gravity and the plastic characteristic of ice.

Glaciers

Here's How

Video Clip 2
30:44 to 31:52—Under the weight of previous years of snowfall, snow melts and forms glacial ice. (1 min. 8 sec.)

Video Clip 3
31:53 to 34:44—Deep crevasses are formed in glaciers by the internal deformation of ice. (2 min. 51 sec.)

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [26:18 - 26:53]. Find out what students already know about glaciers. As a class, discuss the questions posed by SuChin Pak.
- To help students understand the movement of ice crystals in internal deformation, use the analogy of a car braking on a pile of leaves. Have them consider the various layers of leaves under the car tires. How does the top layers of leaves move? The bottom layer? (When this happens, each layer of leaves in the pile moves farther than the layer below it.)
- The cornstarch glacier should not be excessively "soupy." It should be more solid than liquid.
- You may wish to prepare the plastic soda bottles before class. If students are cutting the plastic bottles, remind them to follow established classroom safety procedures.
- Students can store their cornstarch glacier in a covered margarine container if the activity is going to be continued an additional day.
- The lumps of clay should be small—about the size of popcorn kernals.
- Students often wonder whether the ice in the freezer at home has the same characteristics that glaciers have. It does, and it is also capable of internal deformation.
- If it is appropriate, view the complete video segment on glaciers after completing the activity.

Preparation
- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 2 for each student.
- Review the information in the Background on page 24.

Engage (Approx. 20 minutes)

Ask the students if they can tell you what Silly Putty and honey might have in common. Invite them to make predictions about qualities in these two substances that may relate to glacial movement.

Prepare a demonstration with Silly Putty ahead of time. At least an hour before class, put a lump of Silly Putty on a book. (You may want to work the putty and make it more flexible before putting it on the book.)

Tell students you are going to use honey to show them an important characteristic of ice. Place a large spoonful of honey on a dish in front of the class and ask students to observe how the honey behaves. (The honey deforms under its own weight and begins to flow to distribute its mass evenly. It does not slide.) Explain that glaciers appear to do the same.

Ask students if they have seen other substances behave in a similar manner. Hold up the Silly Putty that you prepared before class. Ask students what makes it flow. (gravity) Explain that although students cannot see the Silly Putty flow, it has moved since it was put on the flat surface before class. Form the Silly Putty into the shape of a ball and pull it apart slowly. Tell students that ice also stretches under enormous pressure. Form the Silly Putty into a ball once more and pull it apart quickly. This time it breaks apart. Tell students that when ice can no longer stretch, it also breaks apart. This is why crevasses form in glacial ice.

View Video Clip 2 [30:44 to 31:52]. Ask students how the shape of the ice crystals contributes to internal deformation. (The ice crystals become flat and parallel to each other, allowing them to slide.) Ask students for the two types of glacial movement. (Basal sliding and internal deformation.) Ask students to give the cause of basal sliding. (Meltwater lubricates the glacier at its base.)

View Video Clip 3 [31:53 to 34:44]. Ask students what the cracking sounds are in the glacier. Ask them how crevasses form. Use a deck of cards to illustrate the principle of internal deformation. Place the deck of cards on a desk. With your hand, press down and slowly forward until the top card has moved about 15 cm. The cards will slide in a way similar to the movement of ice crystals in the video. Ask students which cards moved farther—the ones on top or the ones on the bottom of the deck. (The ones on top.)

Activity 2

Explore (Approx. 25 minutes)

Tell students they are going to make a model glacier with cornstarch and water. Explain that they will attempt to simulate the movement caused by internal deformation.

Have students work in small groups. Tell them to use one part water and two parts cornstarch. Three tablespoons of water and six tablespoons of cornstarch produce a minimal working-size lump of the substance. Tell students to gradually add corn starch to water, stirring each time some is added. When all of the mixture has been combined, students knead the substance and shape it into a loaf.

Next, have students cut across the length of a plastic soda bottle at a 45 degree angle and discard the part that includes the bottom of the bottle. Tell students to set the other half on its uncut side. Below the mouth of the bottle and about three-quarters of the distance from the bottom, have students draw a line with a marker around the inside of the bottles. This will be the starting line for the glaciers movements.

Tell students to place the lump of the cornstarch substance near the mouth of the bottle and allow the surface of the substance to flatten. Next, have students place the three lumps of clay spaced equally across the width of the glacier on the line. Tell students to raise the mouth of the bottle so that it rests at an angle of about 30 degrees and begin timing. Inform the students that their cornstarch glacier will slowly begin to flow down the soda pop valley. Have students record the movement of the glacier every three minutes by measuring the distance that each of the clay lumps has traveled from the line.

Evaluate

1. Without this force, internal deformation cannot take place. What is it? (Gravity.)

2. The thicker the ice the faster the movement. Explain why this is true. (Internal deformation occurs because the ice is deforming under its own weight. The heavier a glacier is, the greater the internal deformation and flowing speed.)

3. Considering what you know about internal deformation, does the phenomenon take place deep inside a glacier or nearer the surface? Why? (Deep inside a glacier for two reasons. First, the snow crystals have to be changed into ice crystals, and this requires weight and pressure. Second, internal deformation itself requires much pressure.)

Try This

The British scientist John Tyndall first demonstrated the plastic nature of ice in an experiment in the 1880s. His hypothesis was the first to explain the forward movement of glaciers. Do some research on John Tyndall and find out how he discovered the plastic nature of ice.

Ancient remains of animals and humans have been discovered in glaciers, most recently in the Alps. Do some research on how the glaciers preserved the findings.

Glaciers are an important sign of the condition of our environment. A lot of research on glaciers is about glacier health—why some glaciers are melting away. Do some research and find out what contributes to the disappearance of glaciers and why this information is important to us.

SILLY ICE

Activity Sheet 2

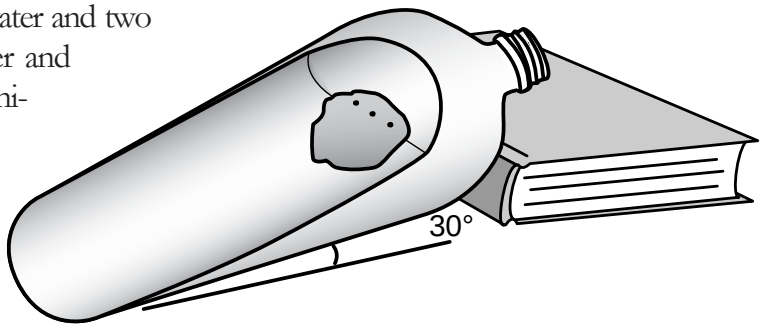
NAME _____ CLASS PERIOD _____

WHAT YOU'RE GOING TO DO

You're going to make a glacier out of cornstarch and water and model the movement of a glacier caused by internal deformation.

HOW TO DO IT

1. Work with a small group. Mix one part water and two parts cornstarch. Three tablespoons of water and six tablespoons of cornstarch produce a minimal size glacier. Start with the water, and gradually add cornstarch, stirring each time some is added. When all of the mixture has been combined, kneed the ball of cornstarch and shape it into a loaf.



2. Cut across the length of a plastic soda bottle at a 45 degree angle. Discard the part that includes the bottom of the bottle, and set the other part of the bottle on its uncut side. Below the mouth of the bottle and about three-quarters of the distance from the bottom, draw a line with a marker around the inside of the bottle.

3. Place the lump of the cornstarch substance near the mouth of the bottle and allow the surface of the substance to flatten. Next, place three small lumps of clay across the width of the glacier directly above the line. Raise the mouth of the bottle so that it rests at an angle of about 30 degrees, and begin timing. The corn starch glacier will slowly begin to flow down the soda pop valley.

4. Predict how the lumps of clay will move. Will one move faster than the others? Write your prediction in your journal. Measure the movement of the glacier by measuring the distance each of the stakes have traveled from the thread every three minutes.

RECORDING YOUR DATA

Predict how the toothpicks Measure the movement of the clay on your glacier.

Clay on left:	Clay in center:	Clay on right:
1. Time ____ Distance____	1. Time ____ Distance____	1. Time ____ Distance____
2. Time ____ Distance____	2. Time ____ Distance____	2. Time ____ Distance____
3. Time ____ Distance____	3. Time ____ Distance____	3. Time ____ Distance____
4. Time ____ Distance____	4. Time ____ Distance____	4. Time ____ Distance____
5. Time ____ Distance____	5. Time ____ Distance____	5. Time ____ Distance____
6. Time ____ Distance____	6. Time ____ Distance____	6. Time ____ Distance____

WHAT DID YOU FIND OUT?

Did one area of your glacier flow faster than other areas? Why?

Was the movement typical of a real glacier? Explain.

Activity 3

Shaping the Earth

As a glacier moves down a mountain side, what happens to the Earth beneath it? Is ice any match for solid rock? Can glaciers make big changes in the surface of the Earth? How?

Getting Ready

Overview

How have glaciers shaped the face of the Earth? How does a glacier shape a valley? Students learn about glacial erosion and simulate the enormous erosive power of a glacier.

Objectives

After completing this activity, students will be able to—

- discuss the erosive effects of glaciers and abrasives
- describe how glaciers have shaped the face of the Earth

Time Needed

Preparation: approximately 15 minutes
Classroom: approximately 1 hour

Materials

For each group of students:

- piece of slate or tile of fired, unglazed clay (7 cm x 15 cm is an ideal size)
- ice cubes
- cup of fine sand and a cup of coarse sand
- paper towels or coffee filters
- sponges for clean-up
- 500 ml beakers
- pennies, iron nails
- photo or textbook illustrations of U-shaped glacial valleys and V-shaped river valleys

Important Terms

abrasive — A substance used to rub away or grind.

erosion — To wear away by the action of water, wind, or glacial ice.

downwasting — When melting at the terminus is greater than the movement forward of the glacier.

moraine — The material deposited at the terminus of a glacier.

Glaciers

Here's How

Video Clip 4
34:45 to 36:05—At the terminal end of the Taku Glacier, Professor Miller and David Heil observe the immense erosive power of a moving glacier. (2 min. 20 sec.)

Preparation

- Set up the computer to play the CD-ROM (or set up the VCR and cue tape).
- Gather the materials for each team of students.
- Make a copy of Activity Sheet 3 for each student.
- Review the information in the Background on page 24.

Guide on the Side

- You may wish to begin the lesson by viewing the Introduction from the Video Menu on the CD-ROM [26:18 - 26:53]. Find out what the students already know about glaciers. As a class, discuss the questions posed by SuChin Pak.
- Students may wonder if the ice cubes have the same hardness as glacier ice—they do.
- Allow the student to try sands of differing coarseness or other types of bedrock material. Granite tiles are often available at building materials stores.
- Tell students that glaciers usually move in one direction, so they shouldn't rub the ice back and forth.
- Remind students to carefully record all their observations.
- Some groups may not succeed in scratching the slate. They should be told that their observations are still very important, that all groups will share their experiences at the end of class.
- If it is appropriate, view the entire video segment on glaciers after completing the activity.

Engage (Approx. 15 minutes)

Show students pictures of glacial valleys and river valleys. Ask the students what the difference is between the two types of valleys. (Glacial valleys are U-shaped, and valleys cut by rivers or streams are V-shaped.) Ask students why the two valley types might have different shapes. (Over many years a river or stream gradually becomes narrower, so it cuts a V-shaped valley. A glacier is wide and touches the valley walls, resulting in a U-shaped valley.)

View Video Clip 4 [34:45 to 36:05] in which Professor Miller and David Heil are at the terminus of the glacier. Ask students where they think the dirt on the ice has come from. (Most is windblown dirt and from the valley walls.) Ask students how far they think a glacier can actually carry rock material. (For the extent of the glacier, some of which are tens of kilometers long.) Ask them if the rock type at the terminus can tell them anything. (Yes, about the types of rocks that are up in higher regions of the valley.)

If a glacier's movement is caused by basal slip, internal deformation, and gravity, do students believe that any of those forces could cease? (Yes, with less mass, a glacier could stagnate and stop moving, though gravity continues to act on the glacier.) Ask students if it is possible for a glacier to move uphill, back up the mountain. (No.) If in one year, the location of the terminus has receded up the valley, what could account for that? (The terminus of a glacier loses mass to melting. The glacier does not actually move backward, but as it continues to move forward, the terminus melts away faster than the glacier moves.) During warm summers and mild snowfalls in winter, more ice melts than usual. This excessive melting is called downwasting, and it gives the impression that the glacier is moving backwards. When glaciers downwaste, they deposit the earth they have been carrying. These deposits are called moraines.

Activity 3

Explore (Approx. 45 minutes)

Tell the students that they are going to investigate the erosion of solid rock by glacial action.

Have students work with a small group of classmates. Explain that they are going to first devise a simple test to find out whether the ice is harder than the slate. Explain that a harder substance will always scratch a softer one, and two objects of the same hardness will generally scratch each other. They may wish to use a fingernail, penny, or an iron nail on both the slate and the ice. They should record their observations.

Encourage students to use their knowledge of glaciers to devise a way to scratch the piece of slate using the piece of ice. They may introduce other materials as well. After each attempt, students should rinse the slate with a small amount of water and collect the rinse water in a beaker. They should examine the water for particles and record their observations. They should then filter the water through a paper towel or filter paper and record their observations.

If no slate-colored particles are observed, it probably means that they haven't scratched the slate.

After all groups have completed several trials, have them compare their results. Did groups make similar observations? How did their knowledge of glaciers help them?

Evaluate

1. Why does Professor Miller compare a glacier to a giant bulldozer? (A glacier is like a bulldozer in the way it plows up the land.)

2. What would happen to the piece of slate if you were able to continue scratching it for several days without stopping? How does this compare to the movement of a glacier? (The slate would be worn away more and more. A glacier continues to pass over the ground, wearing it away a little at a time.

3. How is sandpaper on wood similar to the activity of a glacier? (It is not the paper that removes particles of wood from a board; it is the abrasives on the sandpaper. Similarly, it is not the ice of the glacier, but the abrasives it carries that grind the Earth.)

Try This

The material that is carried and bulldozed by a glacier actually helps to insulate and slow the melting of the ice. Experiment with the speed at which an ice cube melts compared to an ice cube covered with sand. If the rocks covering the ice are dark colored, would the rocks absorb heat and melt into the ice? At what thickness does dark rock material start to insulate the ice?

The material that is moved by the glacier is an obvious form of erosion. What other erosive effects can you notice around school and home?

SHAPING THE EARTH

Student Activity Sheet 3

NAME_____ CLASS PERIOD _____

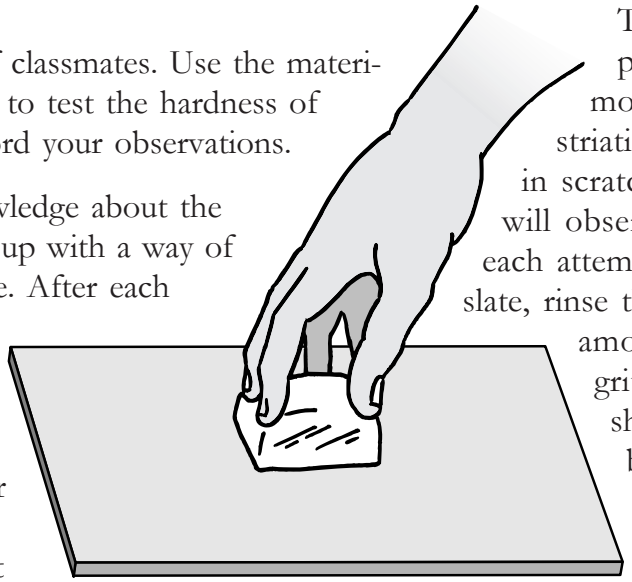
WHAT YOU'RE GOING TO DO

You're going to investigate the ability of a glacier to erode the Earth.

HOW TO DO IT

1. Work with a small group of classmates. Use the materials provided or other materials to test the hardness of the slate and an ice cube. Record your observations.

2. You should use your knowledge about the movement of glaciers to come up with a way of scratching the slate with the ice. After each attempt to scratch the slate, rinse it with a small amount of water. Collect the rinse water in a beaker. Record your observations. Then filter the water through a paper towel or filter paper to collect any suspended material. Record your observations.



The scratches that are produced by glacial movement are called striations. If you succeed in scratching the slate, you will observe striations. After each attempt to scratch the slate, rinse the slate with a small amount of water. Any grit that is produced should be saved in a beaker. Filter the mixture through a paper towel to collect any suspended material. Record your observations.

RECORDING YOUR DATA

Record information about your activities in your journal. Include what materials were used and how they were used. Explain the reasons you chose the materials and methods. Include any other observations that you and your group make.

WHAT DID YOU FIND OUT?

Is ice able to scratch the surface of the slate? Why? Does the ability of ice to scratch slate depend on the amount of pressure applied?

Were you successful in scratching the slate?

Does the grit from the ice settle immediately or only very gradually sink to the bottom of a beaker of water. When the grit is filtered and dried, is some of it light enough to get picked up by the wind? What consequences could this have for the environment if the grit carried by glaciers can be carried by the wind?

Credits

CD-ROM PROJECT STAFF

KTCA TV, NEWTON'S APPLE MULTIMEDIA

Dr. Richard Hudson
Director of Science Unit

David Heath
Lee Carey
Curriculum Development Managers

Cori Paulet
Paddy Faustino
Curriculum Development Coordinators

Edward Voeller
Lesson Editor

Jeffrey Nielsen
Additional Resources Coordinator

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Susan Ahn
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Associate Producers

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NEBRASKA EDUCATIONAL TELECOMMUNICATIONS

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Minneapolis, MN

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REVIEWERS

Charles Addison
Minnesota Earth Science Teacher's Association

Micheal John Ahern
Mentor Teacher, Science and Math
Redwood, CA

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Watertown-Mayer Middle School
Watertown, MN

Zan Austin
Strickland Middle School
Denton, TX

Jon Barber
North Oaks, MN

Rebecca Biegon
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St. Paul, MN

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South Dakota Geological Survey

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University of Minnesota - Dept. of Surgery

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Steve Dutczak, Ph.D.
NASA

Richard Erdman
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Los Angeles, CA

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Fortuna, CA

Mike Garcia
University of Hawaii

Chris Gregg, A.B.O.C.
Inver Grove Heights Family Eye Clinic
Inver Grove Heights, MN

Rick Grigg
University of Hawaii

Deborah Harden
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Gloriane Hirata
San Jose Unified District

Margaret K. Hostetter, M.D.
University of Minnesota

Neil F. Humphrey
University of Wyoming

Lisa Hunter, Ph.D.
University of Minnesota

Sally Jenkins
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The Blake School
Hopkins, MN

Leslie Kline
Metcalf Junior High
Burnsville, MN

Tom Krinke
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Maple Grove, MN

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University of Texas-Arlington

Cynthia MacLeod
Sabin Early Childhood Education Center
Portland, OR

Robert March
University of Wisconsin-Madison

Shannon Matta, Ph.D.
Minneapolis Medical Research Foundation

Ken Meyer
Coon Rapids High School
Coon Rapids, MN

Lou Mongler
Mexico High School
Mexico, MO

Credits

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Vineland Elementary School
Pueblo, CO

John Musso
Pueblo Technical Academy
Pueblo, CO

Debbie Nelson
Bay Trail Middle School
Penfield, NY

Jack Netland
Maple Grove High School
Maple Grove, MN

Joyce Nilsen
Technology Learning Campus
Robbinsdale, MN

Ingrid Novodvorsky
Mountain View High School
Tucson, AZ

Jon Pedersen
East Carolina University

MaryBeth Peterson
Roosevelt Elementary
Minot, ND

Alberto Ramirez
Spanish Translator
Miami, FL

Bev Ramolae
Technology Learning Campus
Robbinsdale, MN

Brad Randall
Osseo Area Schools
North Maple Grove, MN

Gina Roetker
Strickland Middle School
Denton, TX

Fernando Romero
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Dr. Lawrence Rudnick
University of Minnesota

Hank Ryan
Mounds View High School
Arden Hills, MN

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Maclester College
St. Paul, MN

Larry Silverberg
North Carolina State University

Jaine Strauss, Ph.D.
Macalester College
St. Paul, MN

Thomas Walsh, Ph.D.
University of Minnesota

Steve Wartburg
Fortuna Elementary
Fortuna, CA

Randy Yerrick
East Carolina University

FIELD TESTERS

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Chaminade College Prep
St. Louis, MO

Laura S. Berry
Orland Jr. High
Orland Park, IL

Lance Brand
Driver Middle School
Winchester, IN

Lorene A. Chance
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Elizabeth Cordle
Montgomery Middle School
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Kenosha, WI

Dennis L. Engle
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Wadena, MN

Theresa Kistner
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Craig Klawitter
Wadena-Dear Creek High School
Wadena, MN

Linda Love
Hillsdale Middle School
El Cajon, CA

Virginia Madigan
Montgomery Middle School-El Cajon
El Cajon, CA

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Bobbie Faye Ferguson
NASA

Chuck Lang
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